Pictorial Representations of Routes: Chunking Route Segments during Comprehension

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Abstract. Route directions are usually conveyed either by graphical means, i.e. by illustrating the route in a map or drawing a sketch-maps or, linguistically by giving spoken or written route instructions, or by combining both kinds of external representations. In most cases route directions are given *in advance*, i.e. prior to the actual traveling. But they may also be communicated quasi-simultaneously to the movement along the route, for example, in the case of in-car navigation systems. We dub this latter kind *accompanying route directions*. Accompanying route direction may be communicated in a dialogue, i.e. with hearer feedback, or, in a monologue, i.e. without hearer feedback. In this article we focus on accompanying route directions without hearer feedback. We start with theoretical considerations from spatial cognition research about the interaction between internal and external representations interconnecting linguistic aspects of verbal route directions with findings from cognitive psychology on route knowledge. In particular we are interested in whether speakers merge elementary route segments into higher order chunks in accompanying route directions. This process, which we identify as *spatial chunking*, is subsequently investigated in a case study. We have speakers produce accompanying route directions without hearer feedback on the basis of a route that is presented in a spatially veridical map. We vary *presentation mode* of the route: In the *static mode* the route in presented as a discrete line, in the *dynamic mode*, it is presented as a moving dot. Similarities across presentation modes suggest overall organization principles for route directions, which are both independent of the type of route direction—in advance versus accompanying—and of presentation mode—static versus dynamic. We conclude that spatial chunking is a robust and efficient conceptual process that is partly independent of preplanning.

Keywords. route map, map-user-interaction, animation, route directions.

1 Internal and External Spatial Representations

The representation of space and the processes that lead to the acquisition of spatial knowledge and its purposeful employment have bothered researchers from various fields of research for the past decades. From an application-oriented point of view, the still growing need to represent and to process spatial knowledge unambiguously arises in areas as diverse as natural language processing, image analysis, visual modeling, robot navigation, and geographical information science. On a theoretical stance,

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research has examined the ability of individuals to acquire, use and communicate spatial information as one of our prime cognitive abilities that comprises a wide variety of behavioral competencies and uses a large number of sensory cues, such as kinesthetic, auditory, proprioceptive and visual. Moreover, spatial knowledge may be acquired not only by direct experiential access to an environment but also indirectly: Either by inspecting depictions like photographs, maps, sketches, and virtual computer models or, by exploiting written or spoken descriptions.

In this article we interconnect findings on route knowledge with linguistic findings on verbal route directions. In particular, we focus on a specific process of conceptual organization, namely *spatial chunking*,[1] that combines elementary route segments into higher-order spatial segments (cf. section 2). The hierarchical organization of chunks (Anderson, 1993) is fundamental for hierarchical coding of spatial knowledge (Newcombe & Huttenlocher, 2000). Various kinds of hierarchical structures in the conceptualization of our environment have been investigated in spatial cognition research during the last decades. A starting point of this research is the seminal work of Steven and Coupe (1978). They explore the influence of hierarchical organization on the judgment of spatial relations, namely that a statement like *California is west of Nevada* may lead to misjudgments about the east-west relation with respect to San Diego and Reno. On the other hand, numerous experimental studies provide evidence that and how hierarchical components of spatial memory are basic for efficient and successful spatial problem solving (see, e.g., McNamara, Hardy & Hirtle, 1992). Furthermore, another important aspect of the hierarchical organization of spatial memories is the existence of representations of different degrees or levels of spatial resolution, which can be focused on by mental zooming in and zooming out of representations (cf. Kosslyn 1980).

We investigate the conceptual process of spatial chunking via the analysis of verbal data. Instead of identifying elementary route segments to form a complex sequence of route directions (e.g. *you pass a street to your left but continue walking straight on, then you come to a three-way junction, where again you keep straight on until you come to a branching-off street to your right. Here you turn off.*), they can be combined into a higher order segment (e.g. *you turn to the right at the third intersection*). Thus, a zooming in process makes spatial elements at the lower levels accessible and may result in selecting all decision points for verbalization, whereas zooming out results in spatial chunking and yields higher order segments.

In particular we seek to find out whether spatial chunking is operational during the on-line comprehension of a veridical map[2] and the verbalization of a route instruction from this map. To this aim we carried out a case study in which participants had to produce a specific sub-type of route direction, namely *accompanying route directions*, which are produced on-line. The route instructions were *accompanying* in that we encouraged the speakers to image a bike-messenger, whom they accompany by giving verbal descriptions via one-way radio messages, i.e. without responses. More

[1] We use the term *chunking* in the tradition of Cognitive Psychology, i.e., referring to a process that builds up *chunks*. We do not make specific theoretic assumptions about the nature of these processes; especially, our usage of *chunking* is not committed to the SOAR approach (Newell, 1990).

[2] The term veridical map, which contrasts especially to *sketch map*, refers to a map in which focused spatial information is maintained to a high degree. In our case information about distances and angles is preserved.

precisely, the participants were sitting in front of a computer screen displaying a map. They were told to give accurate verbal instructions to a human cyclist traveling through the respective town and thereby directing his movements. They were encouraged to convey the information in such a way that the bike-messenger could follow their instructions without having to ask for clarification. The on-line aspect was enhanced by a *dynamic presentation mode*. In this condition, the route was presented as dot moving through the map leaving the verbalizers little if any cues on the route's continuation. Moreover, we largely impeded preparatory planning processes for both presentation modes: The speakers neither received prior training nor were they presented examples before the actual task. Since we focus on the conceptual chunking processes on part of the *route instructor*[3] (rather than the addressee, i.e., the bike-messenger), the accompanying route instructions were given without hearer feedback (cf. section 3 for a detailed description of the setting). If spatial chunking is a general feature in spatial cognition and thus in route directions, the question arises how the presentation mode may affect this conceptual process (cf. Hegarty, 1992; Morrison, Tversky & Betrancourt, 2000).

Route knowledge and verbal route directions have widely been studied from a variety of viewpoints because they provide a richness of empirical cues about the processing of spatial information from different knowledge sources (e.g. Schumacher, Wender & Rothkegel, 2000; Buhl, Katz, Schweizer & Herrmann, 2000; Herrmann, Schweizer, Janzen & Katz, 1998). Route directions are especially apt for investigating the relation between two types of external representations, *graphical* and *linguistic*, and potential intermediatory internal representations and principles (cf., e.g. Tversky & Lee, 1999). This is the case as they are usually conveyed either by graphical means—i.e. by illustrating the route in a map or by drawing a sketch-map—or, linguistically—by giving spoken or written route instructions—or by combining both kinds of external representations.

In most cases route directions are given *in advance*, i.e. prior to the addressee's actual action of wayfinding or navigating. In-advance route instructions may be conveyed in situations, which permit different amounts of pre-planning, for example, from 'writing a route instruction for colleagues to help them find the site of a meeting' to 'having to answer the sudden request of a passer-by in a wayfinding situation'. These settings vary according to certain parameters. They have in common, though, that the instructors will start from their spatial knowledge, actually, from that part which regards the requested route. But there are different cognitive tasks to be performed, depending on whether the route instruction is entirely generated from memory, or, in interaction with a map-like representation. In general, spatial cognition research has so far been primarily based on the investigation of spatial representations that are built up from direct experience with the physical world. In most cases the participants were familiar with the environment in question and the empirical investigations were targeted at the participants' long-term memory representations of the respective surrounding, i.e. *spatial mental models* as activated long-term memory representations (Johnson-Laird, 1983) or *cognitive collages* (Tversky, 1993).

In comparison, there are fewer results as to what extent internal representations are built up from external representations of space, namely topographic maps, thematic maps, and sketch-maps and how these representations may differ from those based on

[3] Here and in the following we call the speaker who produces the route description, the *route instructor*, or, *instructor* for short.

real-world experience (but see, e.g. Thorndyke & Hayes-Roth, 1982). Generally, the primary role of external representations is their use in solving complex problems by decomposing the representations that are employed in processing the task in external and internal portions (cf. Zhang & Norman, 1994; Zhang, 1997). However, recently, there has been a growing field of research exploring the interaction between external and internal representations (cf. Scaife & Rogers, 1996; Bogacz & Trafton, in press). This also holds for the interaction between map-like representations and spatial cognition (cf. e.g., Barkowsky & Freksa, 1997; Berendt, Rauh & Barkowski, 1998; Casakin, Barkowsky, Klippel & Freksa, 2000; Ghaëm et al., 1998; Hunt & Waller, 1999). In the following sections we review the notions of route knowledge and route directions and explicate our theoretical considerations about the construction of route directions from an external pictorial representation. We clarify the types of external and internal representations in order to specify the spatial chunking processes. Subsequently we present and discuss the results of our case study and conclude with an outlook on future research.

2 External and Internal Representations in Route Knowledge and Spatial Chunking

Route knowledge is characterized as the knowledge about the actions to be performed in the environment to successfully traverse paths between distant locations, especially between an *origin* and a *destination*. Starting from knowledge about landmarks, route learners seem to construct distance and orientation relationships between these fundamental spatial entities and thus come to identify connecting routes between them (Thorndyke & Hayes-Roth, 1982; Golledge, Dougherty & Bell, 1995; Golledge, 1999). Route knowledge is generally assessed by two methods. The first, the *distance estimation task*, where participants have to estimate the distance either between two objects or between themselves and an object. The second, *landmark sequencing*, requires the participants to judge, which of two pictures depicting landmarks located on a route, shows the landmark that would be encountered first coming from a predefined direction. Major features of route knowledge are, first, that it is learned for accomplishing a specific task (mostly, getting from the origin to the destination). Second, that it is based on an egocentric perspective (left and right turns are learned with respect to the body's—actual or imagined—orientation and direction of travel). And third, it is perspective-dependent, meaning that it is most useful when employed from the same viewing perspective as it is learned from (Herrmann, Buhl & Schweizer, 1995). The acquisition of this type of spatial knowledge seems to be primarily based on direct experience.

There is a growing body of research, though, showing that route knowledge can also be acquired from external media (cf. Bell, 1995; Schumacher et al., 2000). For the most part static graphical representations—maps and route sketches—are investigated, while dynamic media for route knowledge learning, like in-vehicle, hand-held and roadside information systems, are still less common. But they are gaining prevalence, which is partly due to the fact that enabling a more efficient distribution of trips over time and space can help limit urban traffic congestion. In parallel to their increasing availability, the cognitive aspects, which underlie the use of digital navigation aids, receive augmented attention. (Advanced River Navigation, e.g. http://www.elna.de/de/03/01/01/02/; Tversky & Lee, 1999; Agrawalla, 2000; Wahlster et al., 2001).

2.1 The Construction of Route Knowledge from External Representations

In the past, maps[4] were often analyzed as semiotic systems (cf. MacEachren 1995) rather than exploring, how map-users conceptualize the information conveyed in the medium. Yet, recent research has acknowledged that maps are a specific—culturally outstanding—class of external representations that can be characterized by the set of tasks for which maps are regularly applied, namely, spatial problem solving. Particularly, there is a close correspondence between classes of spatial—or more precisely, geographical—problems, on the one hand, and types of maps, on the other hand.

Maps are typically multipurpose means of spatial problem solving: A city map is an external representation to help the user in finding a way from an origin A to a destination B, where A and B span up a variety of potential way finding problems. Even more specialized sketch maps like those designed for finding the way to a specific shopping mall or a chosen hotel are not entirely determined on an individual way finding process: While they are fixed with respect to the destination, they usually make this destination accessible from a (limited) number of origins.

In contrast to such multipurpose external representations for *navigation* and *way-finding* stand specifically tailored means of *way directing*, as verbal route directions, hand drawn sketch maps, or visualizations as well as textual route descriptions produced by computational assistance systems, for example, in car navigation systems.[5] In the following, we discuss such a type of external representation that is intended for assistance in solving one individual problem, namely giving route directions from an actual origin A to a chosen destination B. In other words, for each pair A and B—constituting a set of routes—a specific route map visualizing the selected route is created and presented to the instructor, whose task it is to simultaneously comprehend and verbalize the route.

This entails that the internal spatial representations of the respective route and its environment, we are concerned with in this paper, are *constructed* rather than inspected during the route direction task. On the one hand, they are therefore likely to resemble the kind of internal representations built up in a concrete navigation situation, where a map is used in order to solve a way-finding problem in an unknown environment. On the other hand, they probably differ from these, in that the instructors are not trying to keep a route or part of it in mind in order to direct their own movements. Rather they give the route instruction while visually sensing the route presented to them in an as yet unknown map. Hence they likely to adhere to the spatial features of the stimulus map because the map itself is veridical and exhibits the spatial layout of the route and its spatial surroundings non-discriminately. In both

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[4] In the following, we use the term *map* generically to refer to various kinds of map-like external representations of space. We will indicate those cases, where a more specific interpretation is intended.

[5] On these different means of route directing, see, for example, Habel 1988, Freksa 1999, Tversky & Lee 1999.

respects the supposed internal representations for this specific situation might differ from spatial mental models and cognitive collages, which are both considered representations in long-term memory.

2.2 Animation in Pictorial Representations

The major—abstract or rather geometric—property of routes is that they are linear, ordered structures (cf. Eschenbach, Habel & Kulik, 1999; Tschander, Schmidtke, Eschenbach, Habel & Kulik, 2002). The two relevant aspects, namely *linearity* and *ordering*, can be taken into account in map-like representations by different ways of route visualization. Common means are: First, a line, which respects linearity (cf. Figure 2) and second, a line augmented by arrows or arrow-heads, which are conventionalized ways to symbolize orientation of a line. Most recently, dynamic presentations, for example, a distinguished entity moving through the map (cf. sect 3), gain increasing importance in accordance to a growing availability of electronic, stationary, hand-held, and in-car navigation aids. In the case of a dynamically presented route, temporal ordering corresponds to spatial ordering of the route.

In the current paper, we use the first (solid line) and the third (moving dot) means for presenting the stimulus route to the route instructors. The logic behind this juxtaposition is that with the moving-dot condition, i.e. the *dynamic presentation mode*, we enhance the on-line aspect in the verbalization setting. The speakers provide an accompanying route instruction simultaneously to watching the dot moving through the map. In the consequence they might be prone to concentrate on the dot's immediate surrounding which in turn might *discourage* spatial chunking as the chunking process implies the summarization of two or more route segments into one super-ordinate route segment (cf. section 2.3).

With the advent of a growing body of new software tools, current research on diagram understanding has begun to investigate the impact of animated, i.e. dynamically presented, pictorial representations on cognitive processes such as comprehension and reasoning (e.g., Hegarty, 1992). The results are as yet heterogeneous because researchers concentrate both on different kinds of pictorial representations (maps, weather charts, graphs, 3D-forms, etc) and different aspects of cognitive processing (imagery, mental rotation, reasoning, etc.). Thus, there is a range of—reserved to optimistic— estimations about the effects of animation in pictorial representations. While some researchers acknowledge that animation aids in the development of mental models and spatial schema skills for three dimensional forms (Barfield, Lim & Rosenberg, 1990; Augustine & Coovert, 1991), others found that animation rather hindered learning and understanding (e.g. Jones & Scaife, 1999; Kaiser, Proffitt, Whelan & Hecht, 1992; Rogers & Scaife, 1997). The latter judgment is based on the finding that animation in pictorial representations often leads to an overload in information, which is hardly integrated into a coherent whole. Morrison et al. (2000) hold that the efficiency of animated graphics is rather doubtful, too. They assert that while animation adds "change over time" to a pictorial representation, this seeming advantage enhances comprehension only in special cases, namely when it succeeds to present micro-steps of processes that static graphics do not present. This finding is akin to the results of Kaiser et al. (1992) who found that even though animation impeded cognitive processing in many cases, it did nonetheless facilitate accurate observation where only *one* dimension of animation was employed.

This exemplary synopsis illustrates, that the question whether and in which way animation influences the comprehension and processing of pictorial representations remains to date unresolved. Furthermore, a universal answer seems unlikely. Rather the impact of animation does most probably depend first, on the specific kind of animation and second, the nature of the cognitive task a particular pictorial representation is designed to assist. The current paper adds to this discussion: We investigate whether there are observable differences in spatial chunking subject to the static or dynamic presentation of the stimulus route in a veridical pictorial representation.

2.3 Route Directions and Spatial Chunking

Verbal route directions are the second distinguished class of external representations to instruct people to find a route. A series of careful analyses from linguistics and psycholinguistics, for example the studies conducted by Denis and his coworkers (viz. Denis, 1997; Denis, Pazzaglia, Cornoldi, & Bertolo, 1998; Daniel & Denis, 1998), provide insights into the mental concepts relevant for route directions.[6] They put forward the assumption that route instructors can structure their route directions by adhering to the ordering of the spatial objects along the route. Thus, route directions seem to be free from the so-called *linearization problem*, a core problem in language production[7]: "The first remarkable feature of route directions is that they offer a type of spatial discourse in which the linearization problem is not crucial. The object to be described—the route—is not a multidimensional entity but one with an intrinsic linear structure. The discourse simply adheres to the sequence of steps to be followed by the person moving along the route." (Denis et al., 1999: 147). However, by analyzing great varieties of route directions, Denis et al. (1999) also found that the addressees of route instructions considered very detailed route directions, where every potential *decision point* (i.e. *choice point* or *turn point*) and every landmark was mentioned, rather confusing and rated them to be less appropriate than sparser ones.

From this we conclude that the linearization problem occurs albeit in a slightly different way in that the information encountered in a linear order still has to be organized: Information units can be grouped together and thus a hierarchical structure emerges. For verbalization this hierarchical structure may be traversed at different levels whereby a verbalization of elements at the lowest level corresponds to adhering to the sequence of elements as they appear in temporal order. The verbalization on higher levels of the hierarchy, however, leaves certain elements unmentioned (Habel & Tappe, 1999). In this sense the route instructors are confronted with the central conceptualisation task during language production, namely to detect a *natural order* in the to be described structure and to employ it for verbalization. Since the concept of a 'natural order' is extremely vague, one target in modern language production research consists in investigating what kind of ordering is preferable to natural speakers (cf. Tappe, 2000: 71). Applying this principle to route instructions we hold that while the route instructors find it necessary to adhere to the general succession of

[6] Further aspects are discussed, for example, by Habel 1988; Maaß, 1994; Maaß, Baus & Paul, 1995, Tversky & Lee 1999, and Freksa 1999.

[7] Linearization means "deciding what to say first, what to say next, and so on" (cf. Levelt, 1989, p.138).

information along the route, it seems preferable to *chunk* some information units—*elementary route segments* in our terminology—together, in order to optimize the amount of information. In route instructions given in advance, spatial chunking and the resulting verbalization of chunked route segments help avoid overload with respect of the addressee's retentiveness, as is exemplified with the contrast between

Turn left at the third intersection

and

You arrive at a crossing, go straight, you pass another branching-off street to your left, do not take this turn, walk straight on until there is a street branching off to your left; Here you turn.

In accompanying route instructions—especially if there is no hearer feedback and the addressee's progression along the route is not entirely transparent to the route instructor—verbalization might not evidence spatial chunking. The instructor might indeed choose to be more detailed in her or his description of the spatial layout and opt to adhere "to the sequence of steps to be followed by the person moving along the route." Thus, to pinpoint the fundamental difference in the verbalization situation of the participants in our study as compared to the studies of, for example, Denis and his co-workers: The verbalizers in our study have perceptual access to veridical information in form of a map. It is not their memory that determines the elements of the route directions but their conceptualization processes. More importantly even, the route directions are not the results of a planning based process, where the speaker imagines a wellknown environment and mentally constructs a route through this environment which is subsequently verbally conveyed to the addressee. Rather, our participants construct the route directions on-line, while they view the respective map (depicting an unknown environment) for the first time.

2.4 Spatial Chunking and Route Instructions from a Map: External and Internal Representations

In the following we discuss spatial chunking in route instructions via analyzing which kind of information surfaces in verbal route instructions. More specifically, we investigate the question: How does ordering information, i.e. the sequence of graphical-spatial 'objects' along the route in the external medium, interact with conceptual processes, especially the spatial chunking of elementary route features? Thus, we have to distinguish between various levels of analysis in the following. On the one hand, we adopt a *medium perspective* to talk about the level of the external representation, i.e. the *map level.* On this level, we find graphical-spatial objects: the signs on the depiction (i.e. map icons) and the graphical structure (i.e. the network of lines representing streets) in which they appear. On the other hand, there are internal representations considered from a *functional perspective*: They are built up for the specific purpose of the route direction and are therefore specific as to the current task. Consequently certain aspects of the external representation, which are—with respect to the task in question—more salient or more important than others, have been transformed from the external representation into internal representations, i.e., they are the primary result of conceptualizing. These internal representations are temporary 'conceptions' of the perceived situation. They are both less detailed and less stable than long-term memory representations like spatial mental models or cognitive collages; they are rather *current spatial representations*. Additionally, under a *procedural perspective* mental processes become apparent that are employed in order to generate functionally adequate route directions.

Table 1. Three perspectives on route directions from maps.

External representation: *Medium perspective*	Internal representation: *Functional perspective*	Task-specific processing: *Procedural perspective*
Spatial Objects:[8] - depicted **intersections** - depicted public **locations**	Elementary route segments - turning at intersection - landmarks	Chunking: Combination of elementary route segments to elementary and higher order route direction elements

The central question is, what determines the internal representation of a route when a route direction is produced from an external medium? To what extent are route directions the result of human-map interaction? To what extent do they have their own characteristics independently of the specific stimulus? Moreover, can we find differences in processing depending on whether static or dynamic information is processed? And, how do these different kinds of information interact with inherent features of route directions? Similar mechanisms have been discussed for route directions in various environments (Lovelace, Hegarty & Montello, 1999). However, the question of whether the same types of conceptualization are at work when route directions are given from an external medium, such as a map, rather than from a real-world or a simulated environment, has not yet received much attention. Furthermore, whether a variation of the route's presentation mode—static versus dynamic route—has an impact on the spatial chunking is widely unclear. As MacEachren points out: "For dynamic maps and graphs, […], the fact that time has been demonstrated as indispensable attribute is critical. It tells us that change in position or attributes over time should attract particular attention and serve as a perceptual organizer that is much stronger than hue, value, texture, shape, and so on."(MacEachren, 1995: 35). In the consequence, we suspect the ordering information of graphical-spatial objects along the route to be more salient when the route is presented dynamically to route instructors.

Like in real-world and simulated environments, the information content of the route map is much greater than the information content of the route direction generated from it. During conceptualization 'innocent' map objects become functional route direction features, for example, an intersection is used as a point of a directional change, or an icon for a public location, like a subway station, is employed

[8] Maps (of this kind) represent real world objects. A distinction can be made between the *object-space* and the *sign-space* (Bollmann, 1993). The term object-space refers to a map without cartographic symbols, i.e. the plain spatial relations of objects are of concern, like in a database. Additionally, for every 'real world' object a cartographic symbol has to be chosen, spanning the sign-space. The salience of an object is not only dependent on its characteristics in the real world (where, for example, a *McDonalds*-restaurant is more salient than a parking lot), it is also dependent on the sign chosen for its representation in the map.

as a landmark. In addition, not every route segment is seized in the same way: Some of them are mentioned explicitly while others are chunked together. In this chunking process elementary route segments are combined, which have, from a non-functional point of view, the same information content as the graphical-spatial objects[9].

Table 2. Perspectives and route elements.

medium perspective	functional perspective	procedural perspective
crossing 1: three branches (go straight)	CROSSING 1: one relevant branch, no directional change	Chunking of CROSSINGS 2-3
crossing 2: two branches (go straight)	CROSSING 2: one relevant branch, no directional change	
crossing 3: three branches (turn)	CROSSING 3: one relevant branch + **directional change** TURN	
OUTPUT => turn left at *the third crossing*		

The chunking process (procedural perspective) accesses elementary route segment (functional perspective), these entities are derived from map objects (external medium perspective), which represent 'real world' objects. However, there are other factors, that influence conceptualization, selection of information and linearization (cf. e.g., Habel & Tappe, 1999). The content of a route direction might also be dependent of factors like the information offered, the time limit (Wahlster et al., 1998), and the salience of map objects and of the depicted real world objects (cf. footnote 8). As we already pointed out, for the dynamic presentation mode, the perceptual saliency conditions could be different than for the static presentation mode.

2.5 Spatial Chunking

We start this section with a short discussion of three features of route conceptualization which play a core role in our investigation of spatial chunking, namely landmarks, decision points and ordering information.

Landmarks. Additionally to a given street network salient geographical features are employed as external reference points often called landmarks. In route directions they function as adjustments between a built up representation and the actual spatial environment and are, moreover, of prime importance for learning and retrieving spatial information. They are general basic organizational features, cues within the route (Presson & Montello, 1988; Golledge, 1999). In our study we reduced the

[9] A similar mechanism applies in the conceptualization of event-structures: Events adhere to a temporal precedence relation induced by their chronological order. Yet in verbalizing events, speakers construct hierarchical event structures and select either sub-ordinate of superordinate event knots for verbalization (cf. Habel & Tappe, 1999).

meaning of landmarks to identifiers of decision points, i.e. a landmark is associated with an intersection in the near vicinity, to allow for reference to the landmark instead of the intersection.

Decision Points. Decision points (DPs) are operationalized as any type of intersection where streets join (as opposed to non-decision points, which are locations along streets between intersections). In other words, at decision points it is necessary to make a decision since there are alternatives to continue, i.e., it is possible to change direction. When acquiring route knowledge more information is coded at intersections of paths, where choices are made, as opposed to between intersections. Decision points receive a lot of attention in route directions as they afford viewpoints to actual and potential navigation choices. Generally, speakers are aware of the complex environmental information they have to encode.

Ordering Information. As mentioned above, routes are curves, i.e., oriented linear objects (cf. Eschenbach et al., 1999). When reaching a decision point, the main question to decide is whether the instructed person has to go straight or has to turn. On the other hand, the instructor—i.e., who produces a verbal route description while perceiving a route map—has to detect in the stimulus route, which configurations along the route constitute decision points. With respect to a particular decision point, the orientation of a turn is the relevant information to communicate. We see turn-off constellations as sections of a path, which divide their surrounding into a left and a right half plan, induced by the orientation of the movement (cf. Schmidtke, Tschander, Eschenbach & Habel, in press). This property is valuable for a functional differentiation of route sides at decision points. They can clearly be discriminated by the value of the angles, which enclose them, one inside angle, being smaller than 180° and one outside angle, being larger. The side with the smaller angle is the functionally relevant side: Additional branching-off streets on the functionally relevant side directly influence the determinacy for decision-making both in navigation and in route descriptions. ‘Turn right’ is an unambiguous expression as long as there is only one possibility to turn right. In contrast to this, additional branching-off streets on the functionally irrelevant side may distort the internal spatial structure of the decision point but do not necessarily result in ambiguity or wrong decisions. As long as instructors let navigators know that they have to make a right turn at a given intersection the number of branches on the functionally irrelevant side are of minor importance.

In accordance with the fact that the linearization problem for route instructions does arise in a specific way (cf. 2.3), the question emerges how parts of the path are chunked and integrated into a route direction and if there are differences in chunking depending on the presentation mode. A ‘complete’ route direction would include every feature along the route. In the case study presented in section 3 we identify decision points and landmarks as being mayor features for spatial chunking. Decision points can be subdivided in two categories: DPs which afford a *directional change*, for short *DP+* and DPs *without a directional change,* abbreviated as *DP–*. Whereas a DP– is a good candidate to be chunked, the DP+ are especially crucial for a route direction because they constitute *change points*. If the addressee misses a DP+, then there is the risk of going astray and loosing orientation. In the consequence, a DP+

should not be seen as 'chunkable' in the specific task of giving a route instruction, since this could result in loosing information that is vital for conveying the route. We identify three ways for chunking the spatial information in between any two DP+.

The first possibility employs counting the DP- that are situated in between two DP+, or, alternatively, between an actual position of the addressee and the next DP+. We dub this strategy *numerical chunking*. It is evidenced by phrases like: *Turn right at the second intersection*.

The second possibility utilizes a non-ambiguous landmark for identifying the next crucial a DP+ and is thus called *landmark chunking* in the following. The employment of landmark chunking becomes apparent in phrases like: *Turn left at the post office*.

There is a third alternative—henceforward called *structure chunking*—that is based on a spatial structure being unique in a given local environment. Such a distinguished spatial configuration, like for example a T-intersection, can serve the same identifying function as a landmark. If the direction of traveling is such that the spatial structure appears to be canonically orientated (cf. figure 1b), the structure as such is easily employable for spatial chunking, resulting in utterances like *Turn right at the T-intersection*. A T-intersection is such a salient feature that it is recognizable, even if the direction of traveling does not result in it being canonically oriented, cf. fig. 1a. Although the intersection does not look like a T-intersection from the route perspective, our route instructors used utterances like, *turn right at the T-crossing* in analogous situations.

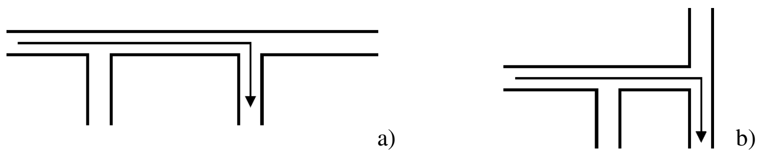

Fig. 1. The uniqueness of a spatial structure, i.e. employing the spatial structure as a landmark, dependent of the direction of traveling.

In all three cases of spatial chunking, the number of intermediate decision points or other route features is not specified a priori. It is sensible to assume, however, that the number of left-out-DP, i.e. the DP without directional change (DP-), is not arbitrary. A route direction like *Turn right at the 25th intersection* is unlikely to occur as it violates processability assumptions that the speaker implicitly applies. In other words, it is part of the addressee model that human agents are not primarily processing quantitative measures in spatial discourse.[10]

[10] The maximal number of chunkable intersections is dependent on the spatial situation and is not in the focus of this research. The respective parameters in instructing a mobile artificial agent will be quite different from that of human agents.

3 A Case Study on Accompanying Route Directions from a Map

To shed light on the research questions raised in the previous sections we conducted a case study with a route presented in a map in two ways, statically and dynamically. With this distinction we aim at gaining insights in the processing of spatial information while producing accompanying route directions from an external representational medium. We are thus starting out from a *medium perspective* (what is the spatial structure actually depicted in the map?) and analyze the language data from a *procedural perspective* (which types of spatial structures are construed by the speakers during verbalization?). According to a long-standing tradition in the cognitive sciences, we use verbalizations as an empirical method to get access to otherwise hardly obtainable internal conceptualization processes. Specifically, we elicited accompanying route directions without hearer feedback. This has the advantage that we got longer discourses, where the structuring of the textual information partly reveals the presumable structure of the underlying internal representations on part of the speakers.

3.1. Material

Giving accompanying route directions from a veridical representational medium, i.e. a map with faithful information on angles and distances ensures that conceptual processes are not influenced by memory constraints, as might be the case for in advance route directions. The stimulus map[11] (see Fig. 2) was built on topographic data of the street network of a middle-sized town in Germany, slightly changed to fit the task in two ways: First, we added different kinds of landmarks which have proved in pre-tests to be easily recognizable. In Figure 2 we present the variant for the German verbalizers; the US-American participants received the same map with the same landmark locations albeit with US-American icons (e.g. McDonald, K-Mart). Second, we inserted a small number of additional branching-off streets in order to aggravate predictions about the route's continuation and thus to make spatial chunking more difficult in the on-line presentation mode. For the same reasons, we indicated only the route's origin in the map (by a visually salient green flag) but did not highlight the route's destination.

The route as depicted in Fig. 2 was presented either as a solid line, i.e. *static presentation mode*, or, as a moving dot, i.e. *dynamic presentation mode*. We chose the route according to the following criteria:

- The overall direction of the route is from right to left, i.e. against the usual reading/writing direction.
- The route is long enough to include a number of left and right turns.
- The route passes different kinds of intersections.
- It allows the participants to use different kinds of spatial chunking.

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[11] The streets of the stimulus are built on the spatial relations of a topographic map, which means that they are veridical with respect to the spatial information that can be inferred from them, for example angles and distances. On the other hand, the graphic realization was simplified and certain features were left out.

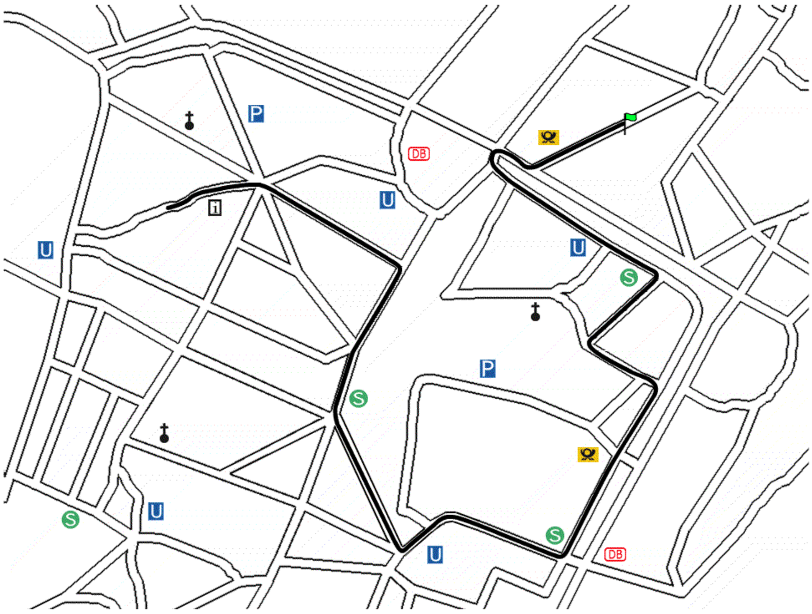

Fig. 2. Static stimulus material. In the dynamic condition a moving dot follows the course depicted by the line, which is not visible neither during nor after the presentation.

As was explicated in section 2.5 the spatial chunking process should be employed for route segments between decision points with directional change, i.e. DP+. If the speakers were to chunk segments containing two or more DP+, they would delete information that is crucial for the successful conveyance of the route direction. Thus, the five regions encircled by bold lines in figure 3 identify spatial structures between two DP+, which are candidates to be undergoing chunking.

The presentation was realized as a *Flash* movie. Presentation time was the same for both conditions (120 seconds) in order to enhance comparability. In pre-test we insured that presentation time allowed for naturally fluent speech production for the dynamic presentation mode. While the dynamic presentation mode provided participants with an implicit time management cue—i.e. they knew that they could speak as long as the dot moved—this did not hold for the static presentation mode. Therefore, participants in the static presentation group were given short acoustic signals after 60sec and 90sec, respectively, in order to be able to estimate the remaining time.

3.2 Participants

Forty students from the University of Hamburg (Germany) and forty-two students from the University of California, Santa Barbara (USA) participated in the study. The German participants were undergraduates in computer science and received payment for their participation. US-American participants were undergraduates in an introductory geography class at the University of California, Santa Barbara, and received course credit for their participation. Two German and three US-American participants had to be excluded from the sample because their language output was hardly comprehensible (low voice quality).

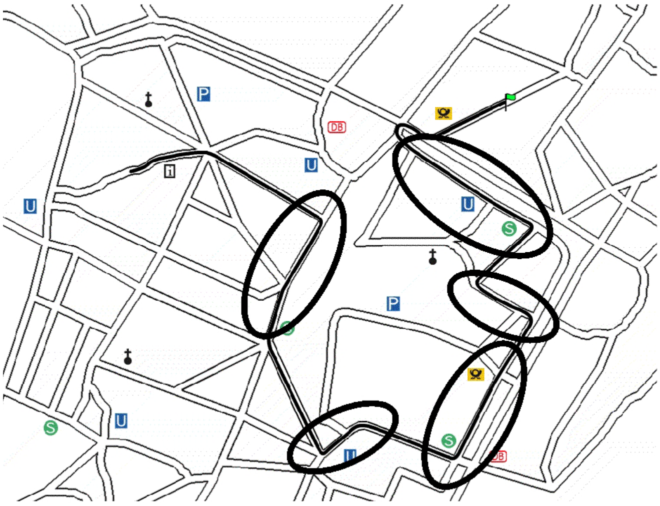

Fig. 3. Route segments that are situated between two DP+ and thus are candidates for spatial chunking.

3.3 Procedure

Participants were divided into two groups, a *dynamic condition group* and a *static condition group*. They were tested individually in an inter-individual design. Written instructions embedded the language production task into a communicative setting:
First part (for both groups).

> You are an employee at the central office of a modern messenger-service. There are plans to create the technical means to observe the messengers' movements on a screen and—for example in case of delay due to the traffic situation—to transmit them alternative routes by radio.
>
> In order to practice, a training scenario has been developed, which we are going to demonstrate now.

Continuation of the scenario with alternations for the static/*dynamic* presentation of the route:

> In this scenario you can see a line/*a dot* that is drawn into the map/ *moves across the map* and that suggests a path, which one of the messengers could take. The green flag marks the starting position. Please try to give the messenger a route instruction that is as precise as possible.[12]

[12] The static condition group was informed about the acoustic signals and their significance (cf. 3.1).

Additionally, participants were encouraged to ask questions and were instructed to watch carefully what happens and to simultaneously produce an accompanying route instruction that is suitable for reaching a destination at the end of the presented route. Subsequently, participants were asked to press an 'O.K' button on the screen to start the *Flash* movie. They saw a countdown from 5 to 1, then the map appeared. The route's origin (as marked by a little green flag, cf. 3.1) was at the same position as the count-down-numbers in order to avoid visual search.

The *dynamic condition group* received the map with a point moving through it. The verbalizers produced accompanying route instructions on the basis of the movements of the point, i.e. they began their route instruction as soon as the point appeared and they stopped shortly after it had reached its destination.

The *static condition group* was presented the same map. Instead of being presented a moving point, the route appeared as a solid line. Participants began their route instruction as soon as the map (with the route drawn into it) appeared and they stopped when their route instruction had reached the destination. None of the speakers ran out of time.

3.4 Predictions

We are interested in the effects of the presentation mode—static versus dynamic—on the processing of spatial information while speakers are producing accompanying route directions without hearer feedback from an external representational medium. More specifically, we focus on the spatial chunking of route segments and map features as is evidenced in the language data. Our predictions were the following:

Prediction 1-Visual accessability influences spatial chunking

In the static presentation mode the route is drawn into the map as a bold black line. It is visually accessible throughout the verbalization task, which allows preplanning; i.e. the speakers' attention may scan route's continuation prior to actually verbalizing it. As compared to this, in the dynamic presentation mode the route's continuation is not accessible to the speakers. Here they are giving the route instruction nearly simultaneously to the dot's movement through the map. Thus, spatial chunking is discouraged. In the consequence static presentation should allow for more spatial chunking than dynamic presentation.

Prediction 2-Speakers avoid spatial chunking in accompanying route directions

In our setting speakers are producing accompanying route descriptions while they are exposed to a spatial environment, they do not know. Thus they can reduce cognitive processing costs in adhering to the local spatial structure at every moment in time and refrain from building up higher order spatial segments. They may think, that under such conditions, spatial chunking is prone to error and leads to misguiding their addressee. These effects should, again, be especially strong for the speakers in the dynamic presentation group who have reduced chances of pre-planning.

3.5 Scoring / Coding of Data

As discussed in section 2.5, we distinguish between different sub-types of spatial chunking during task-specific processing. Chunking is evidenced in the language data, when decision points are not explicitly mentioned but are integrated into super-ordinate units; as a result elementary route segments are combined to form super-ordinate route segments. The stimulus route comprises five route segments that allow for spatial chunking (see Fig. 3) and are separated by decision points with directional change (DP+). This also holds for route segments CD and DE: Even though the intermediate intersection might not at first sight appear to be a DP+, it was univocally treated as such by our participants. Following this logic, we use the route segments encircled in Fig. 1 as data points, i.e. here we counted whether or not spatial chunking occurred. At each of these route segments one or more than one kind of chunking can be employed. More specifically: Numerical chunking can be used in all five route segments, landmark chunking is applicable in segments AB, CD and DE, whereas structure chunking is only available in segments BC and DE. This latter point is closely linked to the interaction with the external medium. In the stimulus map only T-intersections were unambiguously identifiable as compared to intersections with several branching-off streets. In the scoring procedure we accounted for the fact that not all types of spatial chunking can be realized in all route segments by weighting the scores accordingly.

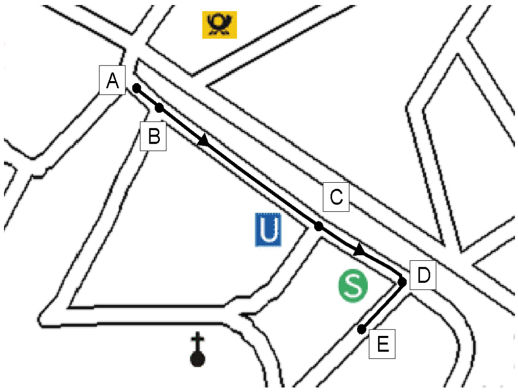

Fig. 4. Route segments (AB, BC, CD, DE) can be chunked to super-ordinate route segments in different ways. A route direction from the origin A to destination E can employ *numerical chunking*, i.e. 'turn right at the third intersection', or by *landmark chunking*: 'turn right after the *S-Bahn* station'. The number of in-between decision points is unspecified.

The participants' route descriptions were tape-recorded and transcribed in full. The transcripts were analyzed in terms of kind and quantity of chunked route segments. For the analysis of content, each transcript was divided into discrete utterances, and the authors rated relevant utterances according to the chunking types listed in Table 3. For each verbalization, we counted the number of complex nouns phrases that indicate a spatial chunking process. In cases where a speaker employed more than one kind of chunking in one phrase, we solely counted the first. An example like: *Turn right at the McDonalds, which is the second intersection* was coded as landmark chunking, i.e. *at the McDonalds*. An independent rater checked reliability of the analysis. Inter-rater agreement was 96% for chunking scores.

Table 3. Categories used to code utterances with examples.

Label	Category Name	Examples
LC	Landmark chunking	"turn left at the station", "go straight after the post office".
NC	Numerical chunking	"turn left at the third intersection", "it's the second street to the right"
SC	Structure chunking	"turn left at the T-junction"

In a first step we kept analyses for the German and the US-American verbalizers apart. Since we did not find significant differences between the two language groups and this paper does not focus on an intercultural comparison, we present the results in one body.

3.6 Results

In general, we found that spatial chunking figures in about 53,8 % of all cases across conditions. Thus our prediction (prediction 2) that speakers avoid spatial chunking in accompanying route directions was not fully met. Instead of adhering to the ordering of the spatial objects along the route in a strict sense, in half the cases they chose to form super-ordinate route segments. Thus our investigation underpins the finding that route instructors are striving to structure the to-be-conveyed spatial environment and to present relevant, non-redundant information. This holds despite the fact that they were producing accompanying route directions on-line.

Figure 5 depicts the mean values for the occurrence of the three kinds of chunking specified above for the two conditions—static and dynamic–, which are weighted according to the possibility to employ each type of chunking at each of the five route segments in question.

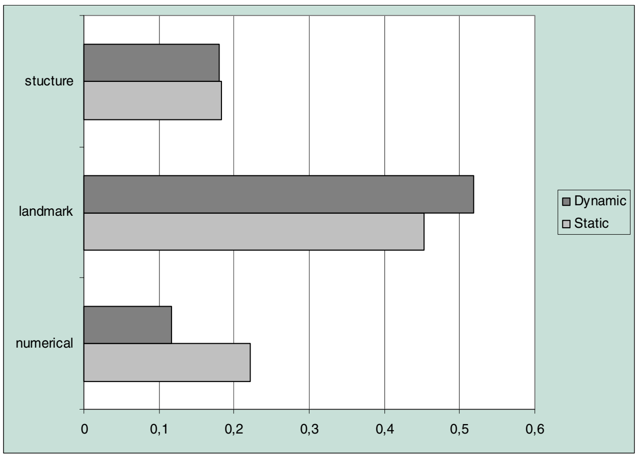

Fig. 5. Weighted mean values (numerical 5; landmark 3; structure 2) for three different kinds of chunking for the two conditions.

The results show the following pattern: Landmark chunking is the most common way to group primary route segments into secondary route segments underpinning the importance of landmarks for route directions from a procedural point of view. The importance of this finding is emphasized by the fact, that for landmark chunking we did not find significant differences between presentation modes. Almost the same pattern figures for structure chunking that was employed to a far lesser extent than landmark chunking: Presentation mode did not yield significant differences. Quite different from this pattern are the scores for numerical chunking: Presentation mode had a clear impact and we found a significant difference (p=0.009, ANOVA).

3.7 Discussion

As we see from the results of the case study, spatial chunking of elementary route segments is utilized as a helpful and adequate strategy in the production of route directions even in a setting where it adds to the cognitive processing load of the speakers. This holds especially for route directions that are processed during dynamic presentation mode: Here planning processes are aggravated because attention has to orient itself to the near vicinity of the moving dot in order to produce adequate guidance for the addressee. Even though speakers may visually scan the surroundings, the continuation of the route is not unerringly predictable. Thus a description of actions at every decision point—with or without directional change—seemed probable. However, even if verbalizers could in principle use all the information they had access to, they often chose not to do so. For example, instead of explicitly including every intersection along a straight part of the path into the route direction, people were likely to chunk segments together. These findings indicate that our second prediction (prediction 2, section 3.4), i.e. *speakers avoid spatial chunking in accompanying route directions*, was not met in an overall manner. What we found in the case study data was instead, that speakers attempted to use spatial chunking where they found it appropriate to the situation, even if it enhanced cognitive processing costs. This was the case in about half the cases overall.

Moreover, the results presented in section 3.5 indicate that the spatial chunking process especially utilizes landmarks and unambiguous spatial configurations—T-intersections in the stimulus material—in the same manner for both presentation modes. The unambiguous identifyability of T-Intersections seems to result from the interaction with the external graphical medium, i.e. the map. Whereas T-intersections present themselves as a salient feature largely independent of their orientation in a map, they might not function as such in route directions derived from memory of a real-world environment. This issue, however, awaits further investigation.

In contrast to landmark and structural chunking, we found significant differences between the presentation modes for numerical chunking, which is clearly favored in the static condition. These latter finding confirms our first prediction, i.e. *visual accessability influences spatial chunking*. Whereas landmarks and salient spatial structures are visually accessible by quickly scanning the route and are obviously judged by the route instructors to be good cues for guidance, as they are assumed to be recognizable for the addressee of the route instruction independently of her or his current localization on the route, this is not the case for numerical chunking. First, in the dynamic presentation mode it might be difficult for the most part to keep track of the exact number of branching-off streets while producing the on-line instruction.

Second, the instructors have no feedback as to the current localization of the addressee. Therefore, they seem to take into consideration that a direction like *turn left at the third intersection* is to a great extent dependent on the progression of the addressee along the route and therefore prone to potential confusion.

Thus, despite the fact that chunking is an omnipresent characteristic of route directions overriding even the guidance of the presentation mode, there remain differences in the processing of static versus animated presentations.

4 General Discussion

Our research investigates the conceptualization of route segments into super-ordinate chunks during a route direction task, first, from a theoretical point of view and, second, in an explorative study. Theoretically the interaction between different representational formats—internal or external—requires a distinction of representational levels. In the case of user-map interaction it is a medium-perspective as such, a functional perspective and a procedural perspective. To elicit specific conceptual aspects of this interaction, i.e. the chunking of route segments, we collected data during a route direction task where the route was indicated either statically by a solid line, or dynamically by a moving dot. As it turned out from our theoretical considerations and from first results of the data analysis, the linearization process in language production is closely related to the chunking process in the case of verbal route directions generated from routes depicted in a map. Following Tversky and Lee (1999), who propose modality independent building blocks for routes, we assume that chunked spatial representations are not only crucial for language production but also for our conceptualization of routes and graphically conveyed route directions.

While verbalizing route instructions, speakers are thus not confornted with the problem of linearizing arbitrary spatial features. Rather they have to combine elements along a linear structure into sensible chunks. The finding that this occurs similarly across presentation modes is important to note. Even though the dynamic presentation strengthens the sequential character of the route, landmark and structure chunking occur in about the same amount of cases for both dynamic and static presentation. This indicates the existence of route direction principles that override specific characteristics of the two presentation modes to a certain degree. The observed effect may consequently be due to the fact that structuring route segments is part of our everyday life and as such a conventionalized skill that is employed even in demanding situations such as during dynamic presentation. On the other hand, the result that static presentation did not lead to a greater degree of landmark and structure chunking may in part be attributed to empirical findings made by e.g. Hegarty (1992). She found that observers of static diagrams mentally animate them in certain circumstances. If this also holds for statically conveyed routes, the difference between dynamic and static presentation would be diminished. This latter speculation invites subsequent empirical testing.

In addition to the similarities between presentation modes, we also found a significant difference for numerical chunking. This encourages further research in order to elucidate cognitive mechanisms entangled with either of the two presentation modes and to reveal effects of animation in distinguished situations. Furthermore, such research should explicate, in which contexts it is preferable to keep things simple and rather employ static depictions. The latter point is emphasized by research on mental animation of static diagrams (cf. e.g. Hegarty, 1992 and Bogacz & Trafton (in press)). Here the question arises in which cases supplementary animation is prone to hinder diagram interpretation rather than enhance it. In the specific case of route directions further research might also reveal differences between static and dynamic presentation modes that can be attributed to theoretical considerations about different kinds of spatial knowledge, i.e. route and survey knowledge. Whereas route knowledge comprises procedural knowledge of a route as well as an egocentric perspective and thus might profit from dynamic presentation, survey knowledge fosters configurational aspects and a survey perspective, which might be favored by a static presentation mode. These aspects are beyond the scope of the current article and await further investigation.

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